Study on aging performance evaluation of external protective materials for bridge suspenders

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Abstract. The external protection of suspension cables is an important component of suspension cables. This article analyzes the common forms of external protection diseases of cable-stayed bridges, suspension bridges, and suspension cables, and manually simulates the environmental conditions of corresponding influencing factors. Xenon lamp aging test, ozone aging test, salt spray corrosion test, damp heat aging test, and low-temperature aging test are used to determine that temperature is the main factor affecting the external protection of suspension cables, The evaluation index for the aging performance of suspension cables has been proposed, and this research content is of great significance for extending the service life of suspension cables.

Keywords: Bridge Engineering; Stay Cable; outer protection; aging performance

1 Introduction

At present, the external protective materials for suspension bridges, cable-stayed bridges, suspension arch bridges, and other forms of bridges, such as suspension cables, are not easily detected within the normal service life of the protective materials before reaching their service life due to the influence of factors such as sunlight, temperature, and corrosive ion environmental conditions at the location of the bridge, which can cause cracks and other diseases, Causing moisture to enter the interior of the suspension cable and causing corrosion of high-strength steel wires, the corrosion phenomenon continues to deteriorate over time, thereby shortening the service life of the suspension cable. [1-4]The research of this project can systematically solve the problem of the service life of the external protective material of the tension sling in various environments, achieve early prediction of the replacement time of the external protective material, provide scientific basis for maintenance and replacement treatment, and replace it before the performance of the external protective material of the tension sling reaches the normal limit life to prevent the occurrence of diseases and prevent external moisture from entering the interior of the tension sling, causing corrosion of high-strength steel wires, Extend the service life of the lifting rope and improve the operational efficiency of the management and maintenance unit[5-8].

D. Li et al. (eds.), *Proceedings of the 2023 9th International Conference on Architectural, Civil and Hydraulic Engineering (ICACHE 2023)*, Advances in Engineering Research 228,
https://doi.org/10.2991/978-94-6463-336-8_80

2 Analysis of the use of external protective materials for stay suspenders

This paper makes field investigation on the protection of stay suspenders of typical bridges. After investigation and comparison, the main cables of long-span suspension bridges are basically installed with the main cable dehumidification system, the main reason that restricts the development of main cable dehumidification technology is the sealing protection effect of main cable system. There are three schemes of sealing protection, as shown in Table 1.

Table 1. typical scheme of main cable sealing protection.

number	Typical scheme of main cable sealing protection	Typical works	Notes
1	Wire vulcanized rubber sealant (2500μm)+high weather resistance finish	Parrot Island Bridge, Humen Bridge, Xiushan Bridge, Guanshan Bridge	Inland, offshore, across the sea
2	Filament chloro-sulfonated +polyethylene wrapping tape	The Longjiang Bridge, the second Dongting Lake Bridge and the Yangsi Harbour Bridge	Inland,mountainous areas

It is found that for Scheme 1 and 2, “Vulcanized Rubber Sealant + high weather-proof top coat” has better appearance effect and less potential sealing trouble. The effect of imported Hypalon tape is obviously better than that of domestic Hypalon tape, but the stain resistance of imported Hypalon tape needs to be further strengthened. There is still a lot of room for improvement in color hopping, oil resistance and vulcanization stability of domestic tape, and it is difficult to ensure the sealing and protection effect of main cable in severe corrosion environment.

3 Main types and disease forms of external protection of stay cables

3.1 Main types and disease forms of external protection of stay cables

In recent years, the cable protection system of cable-stayed bridge mainly includes two types: one is the protection of cable body with HDPE sheath, the other is the protection of parallel steel strands of cable body with different types of materials, HDPE casing is used to protect the outer layer of the high-density polyethylene. The main disease types are as follows:

The diseases of cable transportation and installation. The cable has to go through a series of procedures to complete the prefabrication in the factory, such as the rigging of

cables, the hoisting of cables, the transportation of cables, the spreading of cables, and the installation and construction of cables.

After the damaged cable-stayed. Bridge is put into operation, the cables are located outside the girder and exposed to the natural environment, and the corrosion is the most serious. The cable HDPE sheath is directly subjected to the adverse effects of corrosive media in the atmosphere environment, and is prone to cracking, breakage, holes, bulges, internal water accumulation and other diseases, which have a relatively obvious impact on the aging and mechanical properties of materials, such as the bridge operation and use stage of the disease. Generally speaking, scratches, cracks and breakage of cable HDPE sheath are common diseases, and holes, joint defects, bulges and accident breakage of cable HDPE sheath are individual diseases.

Diseases in the later stage of Conservation. When the trolley moves along the cables and squeezes the cables when the disease is detected and evaluated in the later stage of maintenance, causing mechanical scratches, abrasions and other diseases. In the late maintenance phase of cable structures, it is usually difficult to observe the defects of Orlando de Lassus structures directly, and it is not possible to carry out comprehensive and accurate daily inspection and maintenance, it may lead to the appearance of cable HDPE sheath disease or further aggravate the disease, and then worsen the overall condition of the bridge.

Unforeseen natural disasters, accidents and other factors. In the actual operation of bridges, such as fire, flood, landslide, earthquake, tsunami, hurricane, explosion, traffic accident, ship-bridge collision, etc. . These series of factors will seriously damage the sheath structure and internal cable-body structure of cable HDPE, even endanger the structural safety and use safety of the whole bridge, unforeseeable natural disasters and other causes of disease.

3.2 Major types and disease forms of outer protection of main cables in Suspension Bridge Bay

The main types of external protection for suspension bridge's main cables include main cable steel wire coating Putty + circular steel wire winding + external coating protection system, main cable dehumidification system + S-type winding wire + flexible coating surface seal, main cable dehumidification system + circular steel wire + wrapped tape, red or zinc putty + circular steel wire winding wire + acrylic polyurethane topcoat, above main cable external protection form main disease form is as follows:

(1) Main cable steel wire coating Putty + round steel wire winding + outer coating protection, this system is the main cable galvanized steel wire external surface coating putty, in the winding round galvanized steel wire, the final coating, the main disease form is the outermost putty cracking, partial coating peeling off and oxidation, corro-

sion medium is easy to penetrate into the main cable through these cracks and steel wire winding layer into the internal corrosion of high-strength steel wire, affect the service life of main cable.

(2) The main cable dehumidification system is sealed by S-type flexible coating. This kind of system is coated with paint after S-type winding and integrated with the dehumidification system. Through the investigation of domestic large Bridges, it is found that the effect is good up to now, and the main disease forms are the phenomenon of local peeling and peeling of the outermost coating.

(3) Main cable dehumidification system Round wire wrap belt, this kind of system after the main cable tightening, the professional special winding machine according to a certain lap width to wrap the tape, through the special heating equipment for hot melt bonding, the main cable to form a closed sleeve, not only to prevent the external humid air and rain infiltration into the main cable, but also to install the dehumidification system to reduce the internal humidity of the main cable to provide basic conditions. Wrapping tape is wrapped by special winding equipment at a certain Angle and lapped to wrap the outside of the main cable. Then heating equipment is used to raise the lapping point of the wrapping tape and make it hot melt bonded to protect the main cable from corrosion and protection. In recent years, it is widely used in long-span Bridges that have been built and opened to traffic. The main disease forms are obvious color difference, color jump, delamination and fading between the light side and the backlight side of the cladding, aging cracking phenomenon, local hollow drum, unwinding, lap creasing and other diseases.

(4) Red lead or zinc putty round wire wrapping acrylic polyurethane topcoat, red lead or zinc putty is used to fill the main cable high-strength steel wire, the putty plays a passivation or cathodic protection role on the main cable high-strength steel wire, and then the surface of the main cable is restrained by wire wrapping and provides a flat working surface for painting. The main disease forms are as follows: Putty is easy to dry, crack and fall off, and the material in this way has a relatively large impact on environmental hazards, and such external protection technology is basically no longer used.

3.3 The main types and disease forms of the outer protection of slings

The main types of external protection of sling include hand-wrapped polyethylene and glass fiber plastic belt, metal casing grouting cement slurry; Galvanized steel wire wrapped with hot extruded high-density polyethylene, double PE sheath, coated with anti-corrosion paint, etc. , the main disease forms are as follows:

(1) The aging of the outer protective material, the polymer polyethylene outer protective sheath will be gradually aging under the action of ultraviolet, oxygen and ozone, and the surface will appear crack after using for a period of time.

(2) when the temperature changes, the sling will expand and shrink with the change of temperature. Due to the difference of material properties, the sling can not be deformed synchronously.

(3) The surface of polyethylene casing is scratched and damaged, which is caused by external force scraping in the course of operation.

(4) The deformation of the outer protection material caused by variable load, under the live load of the vehicle, the sling bears different load, and the deformation of the steel wire and the outer protection material is different.

4 Factors affecting the service life of external protective materials

4.1 Research method

By simulating the environmental conditions of the relevant influencing factors, the material performance aging test is carried out to verify the influence degree of the influencing factors on the external protective materials, so as to summarize and analyze the performance degradation of the following materials, the evaluation indexes of external protective materials are determined to provide reference basis.

4.2 The pilot scheme

Three pieces of 200mm × 50mm rectangular wrapped tape were cut by a stamping sample machine, and each piece was divided into three groups to simulate the environmental conditions of light, oxygen, humidity and heat in the same time, after the accelerated aging test, the mechanical tensile strength was tested, and the tensile strength was compared with that without the accelerated aging test.

4.3 Test raw materials and equipment

The material used in the test is compound vulcanized rubber, and the“Wrapping tape” is used for the external protection of the main cable. According to the test objective and the test plan, the corresponding test equipment is used for the artificial aging test of materials. The specific equipment and instruments used are shown in Table 2.

Table 2. material aging test instruments and equipment.

number	Material Aging test	The instrument and equipment used	Impact factors
1	Xenon lamp aging test	Xenon lamp aging test box	Ultraviolet and half visible light, intermittent rain, high temperature
2	Ozone aging test	Ozone resistance testing machine	Oxygen and ozone
3	Salt spray corrosion test	Salt spray tester	CL^-Corrosion
4	Moisture heat aging test	Constant temperature and humidity box	The combination of temperature and humidity
5	Thermal aging test	Steam aging test box	High temperature

6	Low temperature aging test	Low temperature test chamber	Low temperature
7	Material strength mechanical properties test	Electronic tensile testing machine	/

4.4 The test procedure

Xenon lamp aging test. Xenon lamp aging test is to simulate the effect of sunlight with xenon lamp, to simulate rain and dew with condensed moisture, and to test the tested materials in the cycle of light and moisture at a certain temperature, in a matter of days or weeks, the outdoor hazards of months or even years can be reproduced and changes in the durability of the material evaluated.

The temperature is set at 40℃, the humidity is set at 75%, the light intensity is set at 65 W/m^2, and the test period is set at 168 hours, the tensile strength of the sample was compared with that of the sample without aging test. After Xenon lamp aging test, the appearance of the sample showed obvious fading changes, and the color became lighter and lighter.

Ozone aging test. The ozone aging test is aimed at the characteristic that rubber is sensitive to ozone, and uses the method of environmental simulation to accelerate the process of rubber being aged by ozone, the extent to which cracks or other changes in properties occur on the surface of the specimen at predetermined times by exposing the specimen to an airtight, dark chamber containing a constant concentration of ozone and a constant temperature, to evaluate the ozone aging resistance of the samples.

The test temperature is 40℃, the concentration of ozone is 200 × 10-8, the test period is 168 h. At the end of the test, the tensile strength of the sample was tested and compared with that of the sample without aging test. After the ozone aging test, the appearance of the specimen appears a slight crack.

Salt spray aging test. The salt spray aging test is a method to test the corrosion resistance of materials exposed to salt spray, and the artificial simulated salt spray environment created by the salt spray test equipment is used to test the corrosion resistance of materials, the salt solution was prepared according to the standard and the test temperature was controlled.

The test temperature was 35℃, the concentration of nacl solution was 5%±1% , and the test period was 168 hours. At the end of the test, the tensile strength of the sample was tested and compared with that of the sample without aging test. After salt spray aging test, there is no obvious change in appearance.

Hygrothermal aging test. Under the condition of temperature and humidity, the aging damage of rubber by moisture and heat is mainly manifested by the water vapor permeation and the accelerating effect of heat on the permeation, it is to expose the test sample in the humid hot air environment, through the action of hot air and water vapor,

according to the specified time test sample performance changes, thus evaluating the rubber of heat and moisture aging performance.

The test temperature is 60℃, the humidity is 95%, the test period is 168 hours. At the end of the test, the tensile strength of the sample was tested and compared with that of the sample without aging test. The appearance of the specimen has not changed obviously after the warm and wet aging test.

Thermal aging test. Hot Air Aging test is at a specific temperature, the test time to carry out the aging test, vulcanized rubber at high temperature and atmospheric pressure in the air to carry out the most commonly used aging test, it is used to evaluate the heat resistance of rubber and the protective performance of antioxidant.

The test temperature is 80℃ and the test period is 168 h. At the end of the test, the tensile strength of the sample was tested and compared with that of the sample without aging test. After heat aging test, the appearance of the specimen has not changed obviously.

Low temperature aging test. Low-temperature aging test is to use low-temperature aging box, at a specific temperature on the aging test, used to evaluate the properties of rubber low-temperature materials.

The test temperature is -20℃ and the test period is 168 h. At the end of the test, the tensile strength of the sample was tested and compared with that of the sample without aging test. After low temperature aging test, the appearance of the specimen has not changed obviously.

4.5 Analysis of mechanical properties of aging test

Based on the results of the mechanical strength tests of the materials after the aging test and the measured strength of the materials before the aging test, according to the degree of strength reduction, to determine the main factors affecting the life of stay cable on the impact of the sheath material, and through the study of the strength of the degree of decline, determine the evaluation index of stay cable external protection material.

(1) According to the requirements of the test plan, cut and process the samples of the external protection materials which have finished the aging test to ensure the processing quality of the test samples, and number the related samples in groups, collect and record the related basic data before the start of the test.

(2) The specimen is placed on a universal testing machine for strength testing. The strength device system of the universal testing machine is shown. According to the experimental requirements and points for attention of the tensile strength test of vulcanized rubber or thermoplastic rubber (GB T528-2009), the whole process of the change of the test material is recorded, and the data of the test Stress–strain curve are collected and stored by the relevant computer processing software to ensure the accuracy of the test data.

(3) Collecting and arranging the related test data of the outer protection samples after the strength test, and making the related records, comparing and analyzing the test results of the samples under different influence factors.

4.6 Analysis of test results

During the same test time, the tensile strength was tested after the test by artificial simulating the accelerated aging environment, and compared with the tensile strength of the test without aging test, the range of tensile strength attenuation after aging test is 2% ~ 35.8% , the sequence of aging test influencing tensile strength is as follows: low temperature aging test, thermal aging test, salt spray test, hydrothermal aging test, ozone aging test, Xenon lamp aging test, the results show that the environmental factors which affect the life of the protective material are temperature, corrosive gas, humidity, oxygen and ozone, sunlight.

5 Conclusions

Based on the investigation and analysis of the typical diseases and their causes of the external protection of stay cables, and combined with a series of aging performance tests of the external protection materials of stay cables. The conclusions are as follows:

(1) The evaluation indexes of stay cables are determined, it mainly includes five evaluation indexes: appearance quality, temperature and humidity condition, concentration of corrosive gas, ozone concentration and solar radiation intensity.

(2) Through indoor material aging performance tests, it was found that the most serious factor affecting the aging performance is temperature. The lower the temperature, the faster the material aging occurs.

(3) Sorting out and analyzing the appearance quality defects of the suspension cable, summarizing the common forms of defects in the suspension cable, effectively guiding the daily maintenance work of maintenance personnel.

(4) This research content is of great significance for extending the service life of suspension cables and plays an important role in saving maintenance funds for maintenance units

Acknowledgments

This research was supported by the Special Fund Project for Basic Scientific Research Business Expenses of Central Public Welfare Scientific Research Institutes--Analysis and Evaluation of Aging Performance of Outer Protective Materials of Pull-Down Slings under Complicated Environmental Conditions (Approval No.: 2020-9056).

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